(2.)

On the Nerves *of the* Cornea, *and of their* Distribution *in the* Corneal Tissue *of* Man *and* Animals. By J. V. Ciaccio, M.D., of Naples.

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(Pl. VI and VII.)

Since Schlemm's discovery of the nerves of the cornea up to the present time nearly all observers who have investigated the subject agree that these nerves, after dividing and subdividing, terminate in a wide network, composed of non-medullated or pale nerve-fibres. The ultimate arrangement of this network has not yet, however, been fully pointed out, neither has any one proved whether it exhibits the same arrangement in different animals as in man. With the hope of throwing some light upon a subject at present so little known, I have made many observations on the cornea of the sparrow, eel, frog, mouse, and man, and the conclusions which I have arrived at will be detailed in the paper which I have the honour to bring before the notice of the members of this Society.

The great importance of the present inquiry, I imagine, will be generally admitted. The cornea is endowed only with common sensibility, so that when we have established with certainty the manner in which the nerves terminate in it, we may, with some reason, infer the mode of ending of the nerves in the other parts possessing the same kind of sensibility. By comparing, then, these results with those hitherto obtained by observers, in reference to the ending of motor nerves, the debated question about the terminal distribution of these two kinds of nerves, perhaps, will be finally settled. But this inquiry is as difficult as it is important. Of the many difficulties which I have met with, I shall only now allude to those which seem to me to be the greatest.

1. The first is, that the nerves of the cornea in all their course continually change the plane and direction of their distribution, so that in making very thin sections for microscopical investigation, not only is the relative position of nerves and the adjacent tissues altered, but those nerve-fibres which we observe in the thin sections very often exhibit such appearances that they are hardly recognised by the most experienced eye as nerve-fibres.

2. The second difficulty consists in this, that the optical properties of the nerves and other elementary parts of the cornea are such that, without the aid of some chemical

agents, it is impossible for the nerves to be seen. But by the use of chemical agents the natural aspect of the nerves is always altered, and if we are not very careful in using them, we may destroy the finest fibres.

3. The third difficulty arises from the peculiar structure of the cornea itself, which contains a very large number of corpuscles, with many anastomosing processes. This undoubtedly causes much difficulty in tracing the ultimate nerve-fibres running through its lamellated structure; and if we do not use much diligence in observing, we may mistake the processes of the cornea-corpuscles for the finest nerve-fibres, and draw the erroneous conclusion that there exists an intimate connexion between the nerve-fibres and the cornea-corpuscles.

It seems to me that these three difficulties which I have mentioned, if not totally, can at least in part be surmounted. In fact, if we select for the microscopical investigation those animals in which the cornea is not thick, we shall find that the first difficulty decreases in proportion as the thickness of the cornea which we have to examine diminishes. Hence the cornea of small birds, of the frog, mouse, and so on, are more suitable for investigation than that of man or the larger animals. I have found by experience that in the sparrow's cornea the nerves can be easily seen and traced for a very long distance, because in this little bird the distribution of nerves is more simple than in the mouse and frog, and the thickness of its cornea is such that by only dividing it transversely we are enabled to examine it with high powers. We cannot, in my opinion, completely overcome the second difficulty in the present state of our knowledge; but the only thing we can do is to moderate, in some way, the chemical action of those agents which we are obliged to employ for bringing out the nerves, which lie hidden among the proper fibrous tissue of the cornea. In such a case the best way is to employ only a small quantity of the reagent, because, if required, we can always add more; while, on the contrary, we can never remedy the harm produced by a large quantity. The third difficulty can only be avoided if we are careful in observing. The processes of the cornea-corpuscles generally exhibit such an appearance that they are with great difficulty distinguished from the finest nerve-fibres. Like the nerve-fibres, they become granular by the action of acetic acid. How much this increases the difficulty it is hardly necessary to say. In no other way, therefore, we can distinguish the processes of the cornea-corpuscles from the finest nerve-fibres, but by following both to their respective origins, viz., the

former to the cornea-corpuseles, and the latter to the branches, from which they are derived. I say, candidly, that when I commenced this inquiry, I had fallen into the error of believing that, if not all, at least some of the finest nerve-fibres distributed to the cornea, really terminated in its corpuscles; but a rigid and exact investigation has since convinced me that I was greatly mistaken. I have often succeeded in tracing beyond the cornea-corpuscles some nerve-fibres which, at first, seemed to end in them. The truth is, that sometimes some of the finest nerve-fibres, which could be followed as far as the cornea-corpuscles, could not be traced further on, so that they appeared really to terminate there. But I think this appearance depends on the continuation of the fibre being destroyed either by the pressure of the thin glass, or by the action of the chemical agents which we are obliged to employ. Because if it were not so, the above-mentioned appearance would be more frequently observed.

After these brief remarks upon the great importance and the difficulties of the present inquiry, I shall proceed to state what my observations have shown with regard to the distribution and termination of the nerves of the cornea; and I shall divide, but only for the sake of a clear and methodic arrangement, the whole subject into two parts. In the first part the nerves, with all their peculiarities, will be considered; and in the second, the manner in which they end will be described in detail.

I.—Of the place where the nerves enter into the cornea—of their number and size.

The nerves of the cornea derived from the ciliary nerves pass from the selerotica into the laminated structure of the cornea, rather nearer the posterior than the anterior surface. They are seen at its margin in the form of several fine trunks, which, as they pass in different directions from their entrance, form with the border of the cornea various angles. I have observed that, when the cornea of some small animals, namely, frog, eel, mouse, and sparrow, is transversely divided into two parts, at the microscopical examination, most of the fine trunks divided across their course are found in the section corresponding to the posterior part of the cornea, while the network formed by them is found in the anterior part. The conclusion from this observation is, that the nerves, in entering the cornea towards its posterior surface, after dividing and subdividing, reach the anterior

surface, where they end in a very composite network or plexus.

The number of the nerves of the cornea varies very much in different animals. This number can be determined with some certainty only in small animals, because in the larger ones the cornea is so thick that in order to examine it with high powers, it is necessary to make very thin sections, in which we very often fail to find any nervous trunks, or not more than one or two. In small animals, on the contrary, the cornea is thin enough to be examined microscopically, either entire, or only divided transversely into two parts. According to my observations, in the cornea of the sparrow there are thirty-one nerve-trunks; in that of the mouse twenty-six, and in that of the frog about thirty. I say *about thirty,* because, in a sixth part of the cornea of this animal, I have seen nearly five trunks. Supposing, then, that in each of the remaining parts were the same number, the total sum will be as above. But this supposition is not quite correct, for in the cornea the nerve-trunks are not at equal distances from one another, so that in one part the number of the nerve-trunks may be greater than in another part. In the cornea of the frog, therefore, the nervous trunks may be more or less than thirty.

Some observers have asserted that the nerves of the cornea in man are from twenty-four to thirty-six; but every one who considers the difference between twenty-four and thirty-six, will at once see that this is only a mere assertion, and nothing else. In man, as in other large animals, I believe it is very difficult to ascertain the precise number of the nerves of the cornea. I must say that, in calculating the nerve-trunks distributed to the cornea of the animals above mentioned, I have not taken the slightest notice of those very fine trunklets which, together with the large ones, enter the cornea at various depths.

The corneal nerves also vary much in size. Not only is there a great difference in the size of the various trunks in the same animal, but between those of different animals when compared the one with the other. From my observations, I am led to the conclusion that the nerves in the cornea of the mouse are larger than those in the cornea of the eel, frog, and sparrow.

The manner in which the nerves of the cornea branch.

It is generally admitted that the mode of distribution of nerves to the cornea is effected by dichotomous division.

Undoubtedly this is the general rule, nevertheless, I have observed, although very rarely, in the cornea of the frog and sparrow, some large branches dividing into three or four smaller ones. There are, however, in the mode of branching of these nerves some points worthy of special note, which I shall presently allude to.

Not all the nerve-trunks of the cornea begin to divide at the same distance from its border. Some of them divide as soon as they enter, while others do so after running for some distance through its fibrous tissue. I have sometimes seen two distinct trunks in the sclerotica converging more and more as they approach towards the border of the cornea; but as soon as they arrive there they unite into a single trunk, which enters the cornea and divides in the same manner as the others. At other times I have observed a large trunk running through the sclerotica like a single trunk; but as soon as it reaches the margin of the cornea, it divides into branches, which, as two distinct trunks, penetrate into the cornea, and pass in different directions.

The division and subdivision of these trunks is generally effected at angles more or less acute. It is seldom that we observe a trunk or branch dividing at right angles. The distance from one to the other division varies greatly. In some cases, while from the first to the second division of a trunk there is a great distance, from the second to the third there is very little. As the nerves, however, approach their ultimate distribution, the distance among the divisions becomes less and less. All the branches resulting from these divisions are not of the same size. It sometimes happens that we observe two nerve-trunks of various sizes entering the cornea one close to the other, and while one divides into two branches, the other, without dividing, unites with the smaller branch, and the compound trunk thus formed runs on. It is also not unfrequently observed that, from a trunk before its regular division, a bundle of fibres separates at a very acute angle, which, after a more or less circuitous course, unites with one of the other branches of the same trunk, or with that from another trunk.

The nuclei in connection with the nerves of the cornea.

Dr. Beale, from his numerous investigations upon the peripheric distribution of nerves, has been led to the conclusion that, in connection with all nerve-fibres, there are little oval bodies, or nuclei, which form an integral part of each separate fibre, and increase in number as the nerves approach

their ultimate distribution. This general conclusion of Dr. Beale cannot be accepted as regards the nerves of the cornea. The nuclei, as I have observed, are very numerous in the trunks and primary branches of the nerves of the cornea, but as the nerves reach their termination, these bodies gradually decrease in number. They are frequently seen in connection with single nerve-fibres, but sometimes more than one fibre is seen connected with a single nucleus. As to the number and size of these nuclei, there is much variety. I have found that in the nerves distributed to the cornea of man and the mouse, the nuclei are comparatively more numerous and broader than in the frog and sparrow.

Besides these nuclei connected with the nerve-fibres, I have seen, especially in the frog, another kind of nuclei, which lie on a more superficial plane than the former, and are spindle-shaped and sometimes so bent on themselves as to exhibit the form of the letter S. They are not arranged in the same linear direction as the nerve-fibres, but incline to them obliquely. I have been able to see these nuclei in the trunks of the nerves and the largest branches; and I hold strongly to the opinion that they are the special organs upon which depends the growth and repair of that clear transparent material in which the nerves at their peripheric distribution are imbedded.

I cannot say from my own observations whether the other nerves of common sensation have the same peculiar characteristic as those of the cornea. There are, however, some observations of Dr. Beale which satisfactorily clear up this point. This able observer has investigated and figured in a beautiful drawing the distribution of nerves in the mucous membrane covering the human epiglottis. Every one who attentively looks at this drawing will distinctly see branches of nerve-fibres in connection with triangular as well as with oval bodies. These bodies, however, in comparison with the large number of the nerve-fibres, are very few, and the greater part of the fibres represented in the drawing appear entirely destitute of nuclei. This is not the proper place to discuss whether the bodies alluded to are to be regarded as simple nuclei, or as peculiar organs. I need only remark for the present that the general appearance exhibited by the nerves, which are distributed to the mucous membrane of the human epiglottis, is, with some exceptions, the same as in the cornea. Now if we compare the before-mentioned drawing with those given by the same observer of the termination of nerves in the elementary fibres of striped muscles, we shall find a remarkable difference between them. The motor nerve-fibres

delineated in these drawings are seen largely nucleated. The nuclei in connection with each individual fibre are often equal to the fibre itself in width, and at short distances from one another. Not one of those large oval or triangular bodies often found in connection with the terminal branches of the nerves of common sensation can be seen here. It appears to me, therefore, that upon this progressive increase of nuclei in motor nerves, as they approach their termination, and on the remarkable diminution of them in sensitive nerves, which, besides, are connected at their ultimate distribution with peculiar bodies, we can, with some degree of reason, establish a fundamental distinction between the terminal portions of motor and sensitive nerves. I cannot flatter myself that this conclusion will be accepted as an unquestionable fact by the generality of observers, because more numerous and accurate observations are required for establishing beyond any doubt its exactness. For the present it is enough for me to have made an attempt to point out some peculiarities which are found in motory and sensitive nerves respectively at the periphery. I firmly believe that when comparative investigations have been more advanced than they are at present, we shall find something peculiar not only in the termination of the nerves of motion and common sensation, but also in that of every nerve of special sensation.

The limiting investment of the nerves of the cornea.

The primitive fibres, of which the nerves of the cornea are composed, as it may be easily observed, are in more or less close apposition with one another. This depends upon the nerve-fibres being imbedded in a transparent homogenous substance, which forms not only a common covering to all fibres composing each separate nerve, but also a special one to each single fibre. The nerves in their ultimate ramifications are only separated from the adjacent parts by this material. According to Dr. Beale, the presence of this transparent substance is owing to the changes the nerves are continually undergoing during life, and undoubtedly he has brought forward a sufficient amount of evidence in favour of this view. Notwithstanding, I feel inclined to consider the above-mentioned material as a peculiar form of connective tissue, produced by a special kind of nuclei. Of these nuclei I have already spoken, and have stated the reasons why they are to be regarded as different from the nuclei connected with the nerve-fibres. I believe that this form of connective

tissue has different degrees of firmness in the nerves of different animals, and that in the same nerve its firmness is gradually diminishing from the trunk to its terminal branches. If this supposition is not allowed, the facts which we are observing must remain either unaccounted for, or we must admit that the nerves at their termination lose the common investment, only retaining the special one to each separate fibre. Although the latter supposition has many degrees of probability in its favour, and explains very satisfactorily the continual change of position which the nerve-fibres undergo, as the trunks, dividing and subdividing, reach their ultimate distribution; yet there are some facts which positively demonstrate that, in some animals, the finest nerve-branches are provided with the same common covering as the trunks, from which they originate. Thus I have observed that, in the cornea of the sparrow, the individual nerve-fibres that compose the trunks and all the branches into which they divide, scarcely undergo any change of position. In this small bird the nerves of the cornea in the trunks, as well as in all the branches, exhibit the general appearance of large twigs, which, by dividing and subdividing, gradually diminish in size. So great is the firmness of the connective tissue which holds together the individual nerve-fibres, composing the nerves distributed to the cornea of this bird.

Number, size, and relative position of the primitive nerve-fibres composing the nerves of the cornea; their division and nature.

The number of the primitive fibres which compose the nerve-trunks of the cornea, is found to vary according to their size. But sometimes we observe in animals of different kinds nerve-trunks of the same size, containing various numbers of primitive fibres. This depends upon the different diameters of the nerve-fibres, as some of them are thicker than others. According to my observations in the mouse, the primitive nerve-fibres are larger than those of the frog and man; and in the sparrow they are much finer.

Before the nerve-trunks of the cornea begin to branch, the primitive fibres composing them undergo a very little change of position, but as soon as their branching begins the change of position takes place, and increases as the division of the nerve-trunks goes further on. In different animals this change of position does not occur to the same extent. Thus, for instance, in the frog and eel the nerve-fibres change their relative position very frequently and extensively, but less in

the mouse. In the nerves distributed to the cornea of the sparrow scarcely any change in the relative position of the primitive nerve-fibres is observed. The change alluded to is effected in this manner:—A fibre running close by the side of another is seen to leave it and unite with a new one, with which, after proceeding for some distance, separates again and passes with another fibre or with its first companion.

Some observers have asserted that primitive nerve-fibres are seen dividing, although seldom, in the trunks of the nerves of the cornea, but such division never occurs in the network or plexus formed by them. This assertion is not supported by actual observation. When we consider the number of the primitive fibres contained in the trunks, and compare it with the numerous fibres into which they resolve themselves, we must come to the conclusion either that the fibres of which the nerve-trunks are composed divide and subdivide freely, as the trunks themselves divide and subdivide; or that what appears in the trunks to be a primitive fibre is not a single fibre, but a compound one. I have tried many times to follow some of these primitive fibres as far as I could, and I have always seen them gradually reduced into finer and finer fibres. I feel quite convinced, therefore, that the primitive fibres observed in the nerve-trunks of the cornea are not single fibres, as is generally believed, but compounded, of several finer fibres held together by that peculiar kind of connective tissue already spoken of. Dr. Beale has been led to conclusions of a similar kind from his observations upon the nerves distributed to the mucous membrane which covers the human epiglottis.

It is well known that the opinion generally received as regards the nature of these primitive nerve-fibres, is that the nerves of the cornea "contain fine dark-bordered primitive tubes only at the margin of the cornea, within a zone half a line to one line in average breadth, while in their further course they possess only non-medullated fibres, completely clear and transparent" (Kölliker). In my own specimens such distinction is not observed. All the nerves, from the entrance into the cornea to their ultimate distribution, do not appear to contain any fibre which could properly be called dark-bordered. All the fibres exhibit the same appearance and refract the light in the same way. I have, amongst many others, a specimen in which all the nerve-fibres, from the margin of the cornea to their termination, have been so acted upon by acetic acid as to display a very remarkable granular appearance. With the purpose of ascertaining the chemical nature of these granules I have treated some specimens which

presented such appearance with ether, and have found that some of the granules were readily dissolved by the ether, while others resisted its action. The natural conclusion from this experiment is that the so-called non-medullated or pale nerve-fibres consists of fatty matter in combination with a protein compound. On being disintegrated by the action of acetic acid, both assume the granular form. Nevertheless it must be borne in mind that, although the pale nerve-fibres, by the action of acetic acid, pass through the change I have already mentioned, yet they never lose their outlines, which only become paler and indistinct.

An alteration precisely resembling that which has been described is also effected by acetic acid on the cornea-corpuscles and their branching processes; and the granules thus produced are acted upon by ether in the same way as those of the pale nerve-fibres. This I mention incidentally, because I am not sure whether it has been noted by those who have purposely studied the subject. I believe that a comparative study (histological as well as chemical) of the cornea-corpuscles would afford more positive information upon their nature than we now possess. Careful observations have shown that these corpuscles have not the same appearance and size in man, cat, and mouse, as in the frog, eel, and sparrow.

I must not omit to say, finally, that the nerves distributed to the cornea of different animals are not of the same degree of firmness. I have found that in the sparrow, frog, mouse, man, and fishes, the firmness of the nerve-fibres decreases in the order in which I have mentioned the animals. It is not so easy, therefore, to make out the nerves in the cornea of man and fishes, because the nerve-fibres being extremely soft are so altered by the chemical agents which we are obliged to employ, that it is more difficult to trace them among the other elements of the corneal tissue than in the other instances.

Channels which contain the nerves running through the cornea.

This question, as it seems to me, must be considered from two different points of view. If the term *channels* is here taken in the meaning of grooves or spaces excavated through the fibrous tissue of the cornea, where the nerves lie, the existence of such channels cannot be doubted. But if, on the contrary, the word is understood in the sense in which it is generally used, viz., as signifying tubes with distinct and proper walls, I strongly hold that, in this meaning, such

channels do not exist at all in the cornea. I have never succeeded in seeing one of these channels, and I am convinced that the nerves distributed to the cornea are not separated from its fibrous elements by any other means but by that special transparent material in which they are imbedded.

II.

In the first part of this paper I have spoken of all those peculiarities which are found in the nerves of the cornea; I propose, in this second part, to explain the manner in which they terminate, and also their relation to the cornea-corpuscles.

I have studied this point with all possible attention, and I can state positively that the nerves of the cornea do not terminate in free extremities. I have often succeeded in tracing some of the nerves from their entrance into the cornea to their terminal distribution, and I have observed the union of the ultimate branches one with the other. But, if the nerves of the cornea do not end by free extremities, in what manner are they arranged in their ultimate distribution? The results of many investigations which I have made upon the cornea of several animals, have led me to conclude that the nerves of the cornea terminate in a network or plexus. I attach a different meaning to each of these two terms, which are generally employed almost synonymously. I understand by the arrangement of nerves in a *network*, when the different bands of fibres are not so interlaced with each other as to prevent us from recognising their respective origins; and by the term *plexus*, when such an intermingling of the bundles of nerve-fibres exists, that we cannot distinguish the point of their derivation.

Observation shows that sometimes the network seems to result from the close apposition or coalescence of one branch with another, without any visible interlacement of the primitive nerve-fibres which compose the uniting branches, and at other times from the intermixture of the fibres of one branch with those of another. Hence two varieties of network; the one, which may be called *network by the coalescence of nerve-branches with one another*, and the other *network by the intermixture of the nerve-fibres of one branch with those of another*. With regard to the plexus, as the meshes produced by the inextricable union of the various nerve-bundles may be either large or narrow, so two varieties could also be formed, and called the one *plexus with large*, and the other *with narrow meshes*.

Having advanced these short considerations on the manner in which the nerves of the cornea in their ultimate distribution are arranged, I pass on to say more particularly where I have found these distinctions existing.

1. *Network by the coalescence of nerve-branches with one another.*—I have observed this variety of network in the cornea of the sparrow. The trunks of the nerves, which enter the cornea of this little bird, are seen at different points from the corneal margin to divide and subdivide, and the immensely numerous branches which result from these repeated divisions are frequently observed to anastomose with each other. When a branch is uniting with another no interlacement of their fibres appears to take place; but they seem, so to speak, to fuse into a single larger branch. The branches generally unite themselves at angles more or less acute; sometimes, however, they appear to unite at regular right angles; and when such occurs, one of the branches forming the angle sends out a fibre on each side of the point of junction parallel with the other branch. Thus it would appear from such circumstances that the arrangement in the cornea of the sparrow is the most simple and regular.

2. *Network by the intermixture of the nerve-fibres of one branch with those of another.*—The second variety of network is found in the cornea of the frog and fishes. I have previously mentioned that, in the cornea of these animals, the different primitive fibres which compose the branches spread out and frequently change their relative position. Thence it happens that, when one branch unites with another, a very perceptible interlacement of their fibres takes place. I have often followed some trunks to their furthest branches, and observed that the disposition of these very fine branches is the same as with the larger, and that the anastomoses among them are of the same character as those between the main branches. I think I may safely argue from the above statements that the networks in the frog and fishes are more complicated in their formation than that of the sparrow.

3. *Plexus with wide meshes.*—The nerves which are distributed to the cornea of the mouse terminate in this variety of plexus. The ultimate branches of each trunk unite together in such a manner as to form meshes which have not all the same dimensions, but are in immediate continuation one with the other. The meshes generally assume an irre-

gular, pentagonal, or quadrilateral form, but sometimes they are seen exhibiting other shapes. The bundles of fibres, from the intermingling of which the meshes are produced, are of different sizes, and disposed in curved lines. Very often, from various parts of the meshes, fibres more or less fine are seen to arise, which cross the field of the meshes in different directions; and after a tortuous course, and continually change of plane, either unite with other fibres, which proceed from distant bundles, or with the bundles themselves. These fibres, which, from their thinness, would lead us to consider them as single, are never found in this state, but are made up of at least two fibres, and generally more.

4. *Plexus with narrow meshes.*—From what I have observed, I feel sure that the nerves distributed to the human cornea terminate in a very extensive plexus with narrow meshes. The plexus is not formed by single, separate nerve-fibres, but by bundles, which are in direct continuation with the smallest branches, into which the trunks, by repeated division, are reduced. In some of my specimens these branches may be seen crossing the corneal tissue in different directions, and may be followed for a long distance, before they are observed to divide into the bundles before mentioned. As the fibres which compose the bundles are extremely pale and transparent, and are also greatly softened and changed very soon after death, considerable difficulty exists in the investigation of this plexus, which can only be seen in good specimens prepared in a particular way.

These different kinds of networks and plexuses, which have been described, extend throughout the anterior part of the cornea, and gradually cease towards the posterior portion. It must be observed that the various bundles forming these networks and plexuses are frequently changing the planes and direction of their ramifications, so that each separate bundle during the whole of its course comes into contact with several other bundles. I have before stated that the principal trunks of nerves, on entering the cornea, are very near to its posterior surface, and pass in an oblique direction, repeatedly dividing, and at length reach the anterior surface. In this fact, which seems to me to admit of no further dispute, is found the explanation why, in the whole space over which the networks and plexuses extend, the different branches which enter into their formation are of unequal size, and the finest branches are found in that part of them which lies immediately beneath the anterior elastica lamina of the cornea.

In connection with the nerve-branches or bundles which compose both the networks and plexuses before mentioned, are observed several small bodies, triangular, or quadrangular, or even of an irregular shape. These small bodies are not all of the same size, and some of them appear of a uniform, granular structure, whilst in others I have found nuclei imbedded in the granular matter. These nuclei are prominently coloured by carmine, whereas the granular matter is not, or only very slightly affected by this substance. From these bodies bundles of fibres are seen to proceed in three, four, or more directions, while some other fibres pass close by them without being absolutely connected with the same. In the first variety of networks these bodies are few in number, and sometimes are found just at the point at which a branch is met by another; and in this case they are of a quadrangular form, and at others, at the point where a bundle of fibres bifurcates, and then present a triangular shape. In the second variety the small bodies are more numerous, and may exhibit an oval, triangular, or quite an irregular form, and are found either amongst the fibres which compose the large branches, or at the point of union of the bundles with each other or where they divide. Again, in the first variety of plexuses, the bodies alluded to are generally met with at the angles of the different meshes forming the plexus, and are usually either triangular or quadrangular. They contain granular matter, and sometimes a nucleus may distinctly be seen at their centre or at one of the angles. As to the second variety, I confess I have not succeeded in seeing any of the bodies I had found in the first variety of plexuses. I believe I have failed because the human corneæ which I could get for investigation were not so fresh as is requisite for carrying out successfully such delicate researches. I say, however, that in some specimens from man's cornea I have observed most distinctly very fine nerve-fibres connected with certain small bodies exhibiting a triangular or quadrangular form, but as the fibres ran for a long distance in straight directions, I cannot help doubting their nervous nature.

Now here arises the question: What is the nature of the bodies which have been described? Are they to be considered as special organs connected with the terminal portions of the nerves of common sensation? or are they not at all different from the nuclei which, as I have said before, are observed to be very numerous in connection with the individual fibres composing the trunks and the largest branches of the nerves of the cornea? It seems to me that Dr. Beale, who, so far as I know, was the first to point out the existence of these

bodies in the terminal branches of the nerves distributed to the mucous membrane covering the human epiglottis, and who spoke of them, without any distinction whatever, as nuclei, could have thought them any way different from the ordinary nuclei which are generally found in connection with the nerve-fibres at their peripheral distribution. I regret I cannot agree with Dr. Beale on this point, because I find a remarkable difference between these bodies and the common nuclei. In fact, as observation shows, the nuclei connected with the nerve-fibres are always of an oval form, and equal in breadth to the fibre itself. Each single fibre contains several of them, separated from one another by little intervals, and arranged in linear series. They are seen varying greatly in number, according as the nerves are examined at an early period of development or in the adult state. On the contrary, the small bodies which are connected with the terminal branches of sensitive nerves are often triangular, quadrangular, or may exhibit some other form. As regards the fibres proceeding from them, these are very fine, and the relation they bear to the small bodies differs from that existing between the common nuclei and the nerve-fibres. Their number is not observed to vary according to the different periods of development of nerves, and they only appear to exist in greater number and to be more distinct in those animals in which there is reason to believe that the cornea is more sensitive. Besides, we must add, that the more the nerves approach the full development, the more perfect and complete the structure of these bodies appears to be. I think, therefore, that sufficient difference exists between these two kinds of small bodies to enable us to draw a marked distinction between them. Yet if we are not allowed to consider them as special organs of the terminal portion of the nerves of common sensation, it must still be admitted that they have something similar to those peculiar triangular nuclei which exist in connection with the nerves of special sensation at their ultimate distribution.

It is not my intention to enter into any deep physiological speculations with regard to the office of these special bodies, and the nuclei which are observed in the nerves distributed to the cornea. Yet I cannot forbear expressing my opinion on this subject. I believe that the nuclei are the agents which are concerned in the formation and repair of nerve-fibres which are continually undergoing change during life; while, on the other hand, I hold that the above-named small bodies take an active and important part in the phenomenon of sensation, and are the only organs by means of which the

finest branches of sensitive nerves are brought into relation with the tissues in which they ramify. The opinion I have just expressed seems to me to be corroborated by this fact, that the nerve-fibres which proceed from the ganglion-cells are more or less nucleated. Now I ask, what is the office of these nuclei which are seen in connection with the fibres near their point of origin from the cells? It does not appear very probable that they are concerned in the formation and repair of the fibres while the cells are charged with a higher and more important office. If such a conclusion be not admitted, the function of these nuclei must remain unexplained.

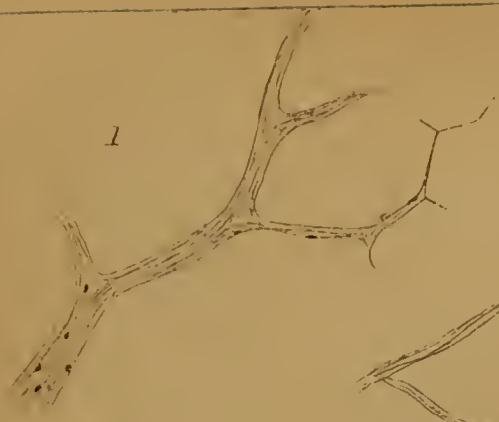
Relation of the terminal branches of nerves to the cornea-corpuscles.

Scattered throughout the fibrous tissue of the cornea are an immense number of bodies which Virchow, who studied them carefully after their discovery by Toynbee, called *cornea-corpuscles.* From each of these corpuscles arise several branching processes, which freely anastomose with each other so as to form an admirable network, which extends over the whole so-called proper cornea. These corpuscles are intensely coloured by carmine, while their processes remain or are very slightly coloured. Now, it must be observed that the branches of the nerves which supply the cornea during their course, are in close contact with the cornea-corpuscles and their processes. I have often seen very fine nerve-fibres passing close by some of these corpuscles, and as their external appearance is the same as that of the processes, which are derived from them, it is difficult to distinguish the former from the latter. It appears to me, therefore, that between the nerve-fibres and the cornea-corpuscles there is no other relation but that of contiguity; because careful observations show that the nerve-fibres always maintain their individuality and never lose themselves in another tissue.

I shall conclude by only adding a few words about the preparations from whose careful examination are deduced all the facts contained in this paper. All my specimens have been prepared in the same way, and preserved as permanent objects in glycerine. In fact, the same process has been followed as that employed by Dr. Beale in his investigations on many of the simple tissues of the body. Most of the specimens have been examined by Dr. Beale, to whom I am greatly indebted for the kind assistance and warm encourage-

ment he has afforded me in the present undertaking, in which I have spared neither time nor labour.

Some observers maintain that the selerotica is entirely destitute of nerves, but I do unhesitatingly affirm the contrary. I have distinctly seen some very fine bundles of nerve-fibres distributed to this coat. These bundles, which arise from the nerves destined to supply the cornea, separate from them at different angles before they reach the corneal margin, and after passing backwards ramify in the fibrous tissue of the selerotica, the bundles anastomosing with each other. I have a specimen from the mouse that evidently proves this fact.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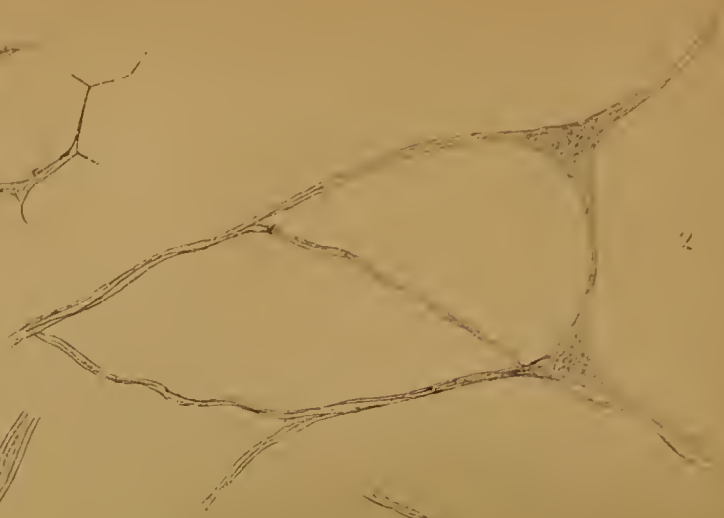
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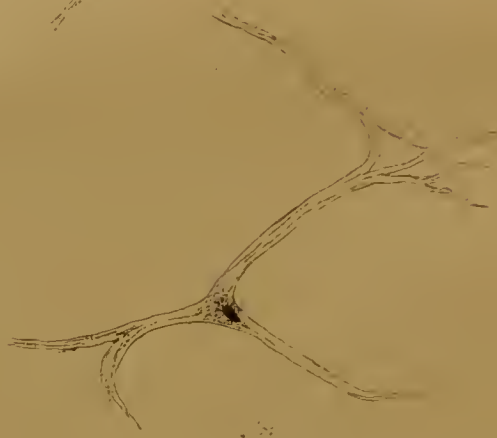
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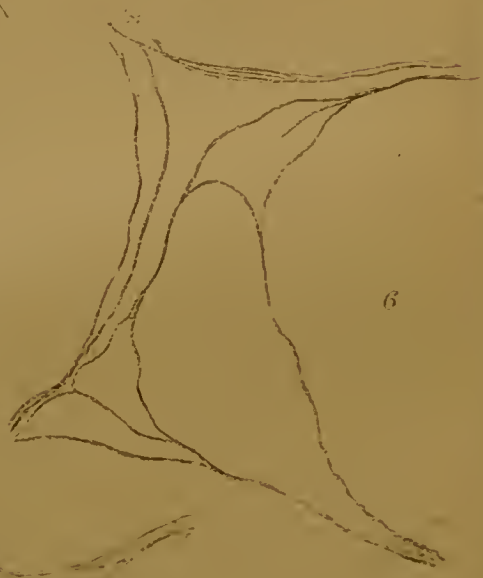
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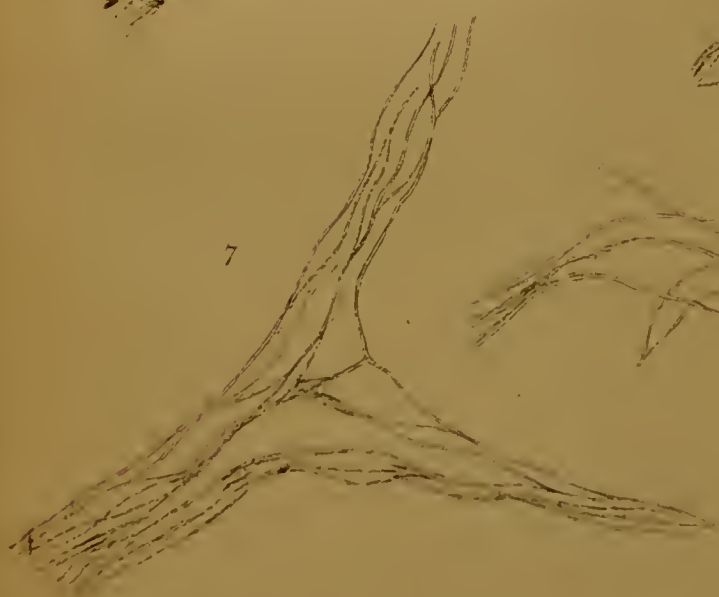
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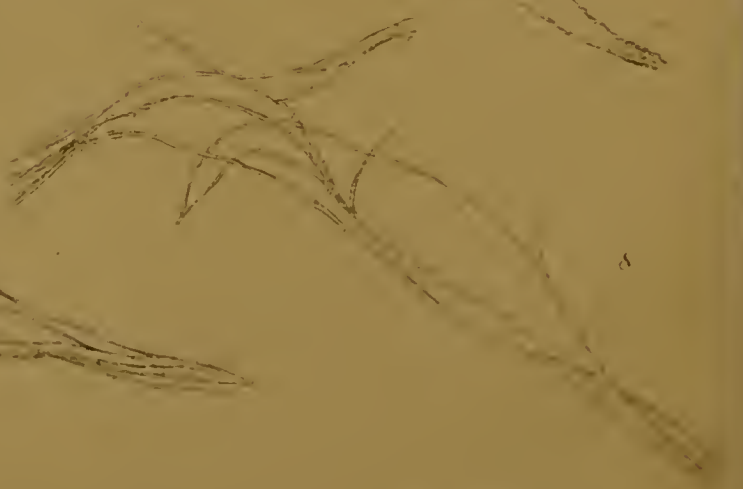
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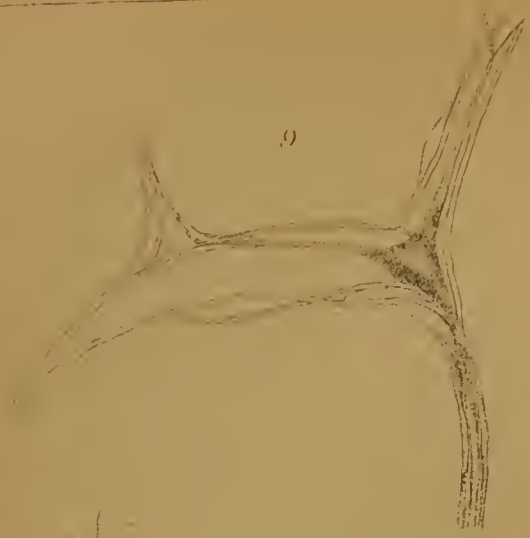
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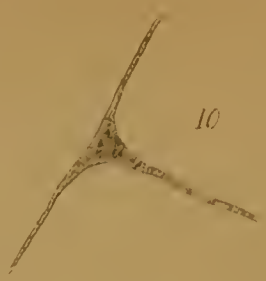
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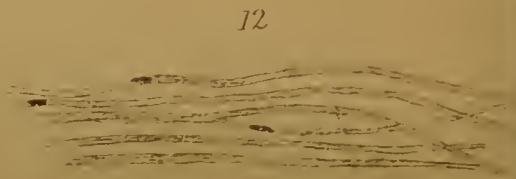
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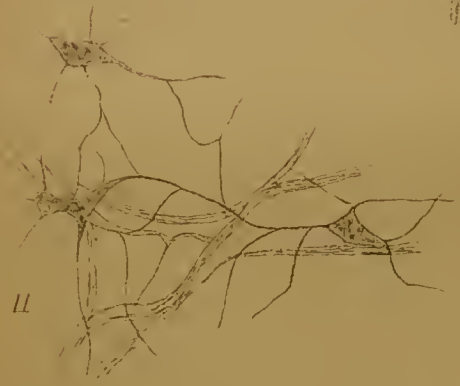
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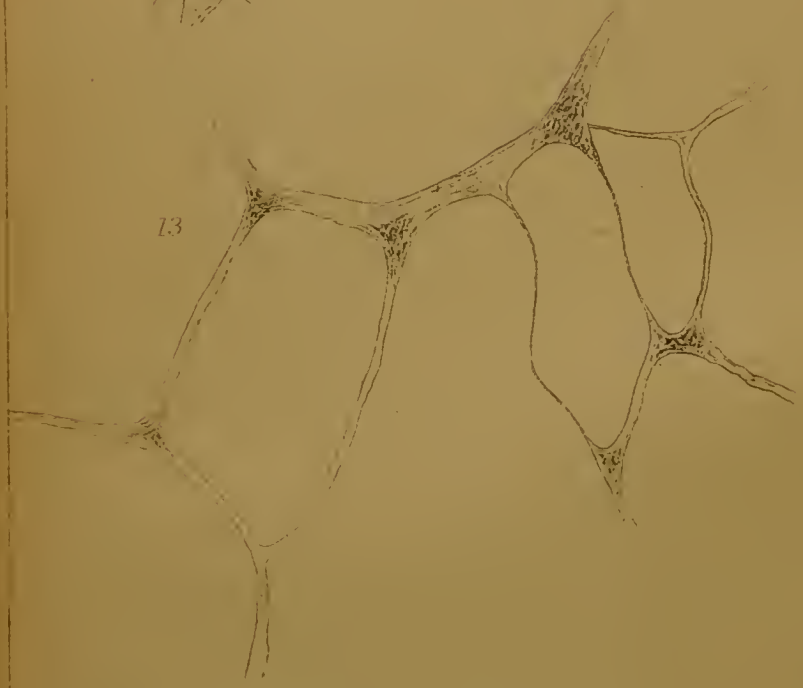
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DESCRIPTION OF PLATES VI & VII,

Illustrating Dr. Ciaccio's paper on the Nerves of the Cornea, and of their Distribution in the Corneal Tissue of Man and Animals.

Fig.

1.—One of the largest nerve-trunks from the cornea of the sparrow, showing the manner in which the nerves branch, the nuclei connected with the primitive nerve-fibres, and the relative position of the latter in the trunks as well as in the branches. × 150.

2.—Shows the manner in which the bundles of nerve-fibres are arranged in the formation of the network in the cornea of the sparrow. Two triangular bodies are also seen in connection with these bundles. × 700.

3.—One of the quadrangular bodies found in connection with the nerves distributed to the cornea of the sparrow. Bundles of nerve-fibres are observed to arise from it in four different directions. Some of the fibres, in passing from one bundle to another, flank one of the sides of the small body, while others seem to proceed directly from it. A nucleus and granular matter are also seen in the part within. × 750.

4.—From the cornea of the sparrow. A. Small, triangular body, with nucleus and granular matter, connected with bundles of nerve-fibres. B. A very small bundle of fibres, which, on meeting another bundle, nearly at a right angle to it, divides into two finer ones, which run in opposite directions, parallel with the other bundle. × 350.

5.—A rather large nerve-trunk, just at its entrance into the corneal tissue. The fibres, of which it is made up, are seen to be nucleated, but they have not the slightest appearance characteristic of dark-bordered fibres. On the contrary, the fibres bear a great resemblance to the so-called gray or gelatinous fibres of the sympathetic. From the cornea of the eel. × 250.

6.—Very small bundles of nerve-fibres forming networks. From the cornea of the eel. × 350.

7.—One of the branches resulting from the fourth division of a large nerve-trunk from the cornea of the frog. The course and continual change of the relative position of the nerve-fibres is well shown. Moreover, in the point where the branch undergoes division, is seen a fine fibre, which seemed to be a single fibre, but really divides into two finer ones, which go in opposite directions. This fact is very frequently observed in the distribution of nerves to the cornea of the frog. No nuclei are observed in connection with the fibres forming the branch. × 350.

Fig.

8.—A and B. Two ultimate branches of two different nerve-trunks, from the cornea of the frog, showing very distinctly the precise manner in which the one branch anastomoses with the other. The anastomoses are effected by the mutual change of the fibres. × 350.

9.—From the cornea of the frog. Bundles of nerve-fibres, forming networks. Connected with them may be seen a triangular body, from which fibres proceed in different directions. Some fibres of the bundles pass close to this body without any intimate connection with it. The triangular body contains granular matter, which appears to have collected in two places, assuming the appearance of two dark spots. × 350.

10.—Triangular body, from which fibres spring in three different directions. From the cornea of the frog. × 350.

11.—Network of pale nerve-fibres, and network of the branches of the cornea-corpuscles, from the cornea of the frog. These two kinds of networks lie on different planes, and the relation between them is well shown. × 350.

12.—Shows the course, size, and relative position of the primitive nerve-fibres in the branches of the nerves distributed to the cornea of the mouse. × 350.

13.—Nervous plexus in the cornea of the mouse. The general arrangement of the bundles of nerve-fibres in the formation of the plexus, and the special bodies connected with them, are well seen. × 250.

14.—One of those special bodies which are seen in connection with the nervous plexus of the cornea of the mouse. Besides a nucleus, it contains granular matter. Bundles of fibres proceed from it in three different directions. × 350.

15.—Another body of the same kind, in which the nucleus has undergone division. From the cornea of the mouse. × 350.

16.—From the cornea of man. Small nerve-branch, which divides into two smaller ones; and from the pressure to which the thin section of the cornea has been subjected, the nerve-fibres of one branch appear separated from one another. × 350.

17.—Shows the manner in which the fine bundles of nerve-fibres are arranged in the formation of the plexus existing in the human cornea. × 350.